AN EVALUATION OF DAY AND NIGHT AERIAL Bt APPLICATIONS FOR CANKERWORM CONTROL IN SIBERIAN ELM SHELTERBELTS

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COVER ILLUSTRATION: At 3 weeks postspray a Bt treated shelterbelt (upper photo) retains substantially more leaves than an untreated shelterbelt (lower photo) in the same quarter section.

ACKNOWLEDGMENTS

We thank Lee Hinds, manager of the Lincoln-Oakes Nursery in Bismarck for providing us with laboratory and storage facilities at the Nursery and for his support of the project. We thank Bill Brandvik, North Dakota State Entomologist, for assisting in early planning of this project and for assisting in shelterbelt selection. Tony Jasumback and Bob Ekblad of the Missoula Equipment Development Center provided valuable assistance in calibrating the spray aircraft, mixing spray formulations, and monitoring weather conditions during hours that spray was applied. We thank Lynn Whyte, formerly of Method Applications Group at Davis, California, for spray deposit assessment.

SUMMARY

A cooperative project to demonstrate effectiveness of Bacillus thuringiensis (Bt) to control cankerworms in shelterbelts was conducted in 1978 by the USDA Forest Service, North Dakota State University, and the North Dakota Department of Forestry.

Bt in the form of Dipel TM® was applied by fixed-wing aircraft using two formulations and two application timings; (A) ½ lb. Bt in 1 gallon of water/acre (1) shortly after dawn and (2) at night, and (B) ½ lb. Bt in 3 gallons of water/acre shortly after dawn.

Most spray was deposited on the 3 gallons/acre treated plots, and highest cankerworm mortality and least defoliation resulted from that treatment (summary table). Although, results were highly variable, analysis showed that results on sprayed plots and untreated plots were truly different.

Results were most consistent among the 3 gallons/acre treated plots. We attribute this to better spray coverage of those shelterbelts because ounces of Bt deposited did not differ significantly among spray treatments.

Night spray results were no better than day spray results. Night spraying by aircraft was more hazardous than day spraying because of reduced pilot vision and location of several high-voltage power lines near shelterbelts in the demonstration area. In addition, effective treatment time was limited at night because it required that occurrence of young cankerworm larvae, suitable weather conditions, and adequate moonlight for enhancement with night-vision goggles coincide. We conclude that night spraying offers few advantages over day spraying.

Operational treatment cost per ½-mile shelterbelt with the 3 gallons/acre formulation of Bt should average between $20 and $30 depending on the number of belts that a pilot could treat in one spray day. Based on the landowner's average investment of about $2,800 in the size belts that we treated, or the average effective crop protection value discounted to the present of about $2,800 per belt, a cost of $20 to $30 per belt to prevent serious defoliation by cankerworms appears to be economically justified.

SUMMARY TABLE OF MEAN RESULTS

Treatment volume/acre and time of application	Spray Deposited			Percent population reduction at 9 days postspray	Defoliation index 1/
	drops/cm^2	gal/acre	oz Bt/acre		
Check	-	-	-	-17.3 2/	3.70
3 gallon, day	21.0	0.45	1.19	58.8	1.30
1 gallon, day	6.5	.14	1.15	36.8	1.52
1 gallon, night	6.8	.20	1.64	42.0	1.56

1/ 1 = less than 25 percent defoliation
2 = more than 25 percent but less than 50 percent defoliation
3 = more than 50 percent but less than 75 percent defoliation
4 = more than 75 percent but less than 100 percent defoliation
5 = complete defoliation

2/ Negative percent mortality represents an increase in larval numbers.

AN EVALUATION OF DAY AND NIGHT AERIAL Bt APPLICATIONS FOR CANKERWORM CONTROL IN SIBERIAN ELM SHELTERBELTS

by
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INTRODUCTION

Siberian elm 5/ shelterbelts heavily infested with spring and fall cankerworms 6/ are often stripped of foliage in early June in North Dakota. Defoliation reduces ability of shelterbelts to protect crops from drying winds and airborne soil, and shortens belt life. Landowners are reluctant to control cankerworms using ground spray equipment and conventional insecticides because fields are usually too wet in the spring to support tractors and sprayers, heavy equipment damages newly emerged crops, many chemicals are highly toxic to honeybees which are abundant, and ground application costs are high. Bt 7/ is a bacterial insecticide which has very low toxicity to beneficial insects and is registered for cankerworm control.

In response to a request by the North Dakota State Forester, the USDA Forest Service funded a pilot project/demonstration in 1978 to assess operational effectiveness of Bt applied aerially during the day and at night against spring and fall cankerworm larvae. This was a cooperative project among the USDA Forest Service, North Dakota State University, and the North Dakota Department of Forestry. The Lincoln-Oakes Nursery in Bismarck, North Dakota, provided laboratory and storage space in support of the project.

OBJECTIVES

Project objectives were as follows:

1. Demonstrate and evaluate the effectiveness of aerially applied Bt for cankerworm control in shelterbelts.

2. Determine the feasibility of night spraying to reduce wind-caused spray drift.

3. Evaluate costs of aerial Bt applications.

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4/ Entomologist, Rocky Mt. Forest and Range Experiment Station, Bottineau, ND.
5/ *Ulmus pumila* L.
6/ *Paleacrita vernata* (Peck) and *Alsophila pometaria* (Harris).
7/ *Bacillus thuringiensis* Berliner.

MATERIALS AND METHODS

We contacted many private landowners in Burleigh County, ND, for authorization to spray their cankerworm-infested shelterbelts, and selected 30 infested single-row belts as test plots. Selected belts were located within a 26-mile radius of Bismarck. Most selected belts were ½ mile long, but a few were ¼ mile long.

Experimental Design

The project was designed as a completely randomized experiment, and each of the 30 plots was assigned one of five treatments at random. We replicated each treatment six times. The only departure from completely randomized assignment of treatments was an exchange of treatments on plots 3 and 7. Both were assigned treatment of 1 gallon of spray formulation per acre, plot 3 to be sprayed at daylight and plot 7 to be sprayed at night. However, a high-voltage powerline at the end of plot 7 created too great a hazard for night spraying.

Assigned treatments were as follows:

Untreated check	
1/2 lb. Bt/1 gal. H_2O/acre	day spray
1/2 lb. Bt/3 gal. H_2O/acre	day spray
1/2 lb. Bt/1 gal. H_2O/acre	night spray
1/2 lb. Bt/3 gal. H_2O acre	night spray

Spray Formulations

We sprayed Bt in the form of Dipel TM® wettable powder. Spray formulations were mixed the evening before or the morning of application. All formulations contained 0.2 percent Rhodamine B Extra S water soluble dye for spray deposit assessment. Formulations sprayed during the day contained ½ pound of Shade TM® per gallon as a sunscreen to protect Bt spores from ultraviolet radiation.

Spray Application

Plots were sprayed within a 48-hour period when sufficient moonlight for night spraying coincided with presence of early larval instars in the plots. Formulations were applied in 50-foot swaths from a Cessna Ag Truck flying 10 feet above the trees at 115-120 mph. The spray system consisted of a hydraulic pump and conventional boom with 14 flat fan nozzle tips (T8008) 8/ for the 1 gallon per acre (gpa) applications and 42 flat fan tips (T8008) were installed for the three gpa applications. Radio communication between the pilot and crews at the plots was inadequate, so crews used semaphore flags to signal the pilot whether or not a plot was ready to be sprayed.

8/ Spray Systems, Wheaton, IL.

The pilot wore night viewing goggles (F4907) 9/ to magnify ambient light during night spray applications.

Day sprays were applied shortly after dawn on 5/27 and 5/28 but cloud cover prevented night spraying on those dates. The 1-gallon night spray was delayed until shortly before dawn on 5/29 because the moon rose late and was partially obscured by clouds. Since there was not enough time to spray the 3-gallon night treatment on 5/29 and the moon rose near dawn on 5/30, the 3-gallon night treatment was canceled.

Sampling

Crews monitored temperature, relative humidity, wind speed, and direction on the plots before and during spray application. They placed 10 pairs of Kromekote® cards to sample spray deposit at 100-ft. intervals beneath the crown peripheries of sample trees, one card on each side of each sample tree per belt. In addition to sample spray drift, 20 Kromekote® cards were placed at 10-foot intervals in a line perpendicular to the belt near its midpoint.

We sampled cankerworm larval populations and foliage five times; the first sample within 48 hours before treatment and subsequent samples at 2, 5, 7, and 9 days postspray. We removed four half meter branch tips from each of the 10 sample trees per plot at each sample visit. The 10 sample trees were located at 100 foot intervals near the middle of each shelterbelt. Two branches were removed from each side of each sample tree, one at eye level and the other at midcrown height, using pole pruners. Live larvae were counted and recorded for each sample branch, and a sprig of foliage bearing at least 10 leaves or their defoliated remnants was removed from each sample branch and placed in a labeled plastic bag. Each 10-leaf sample was viewed by an electronic portable area meter (LI-3000) 10/ and the surface area recorded to show reduction in sample leaf area caused by cankerworm feeding. However, these data were not analyzed further because of extreme variability and because most defoliation occurred after sampling was discontinued.

Leaf samples from a single tree in each of the three spray treatments were removed daily for 7 days postspray, and analyzed in the laboratory to determine Bt spore life in the field. Serial dilutions were prepared from each daily sample and spread plated on five agar plate replicates. Plates were incubated 24 hours at room temperature, and average viable spore counts for the five replicates were computed.

9/ International Electro Optics, St. Louis, MO.
10/ Lambda Instruments Corp., Lincoln, NE.

Tree Defoliation Estimates

During the third week of June, after larval feeding was essentially completed, we revisited the plots to estimate defoliation. Most cankerworms had pupated but an occasional mature larva was observed on the sample trees.

Defoliation in each vertical crown half of each sample tree viewed from each side of the shelterbelt was rated using the following defoliation index:

1 = less than 25 percent defoliation
2 = more than 25 percent but less than 50 percent defoliation
3 = more than 50 percent but less than 75 percent defoliation
4 = more than 75 percent but less than 100 percent defoliation
5 = complete defoliation

An average of the 40 defoliation indices recorded for each plot, four per sample tree, was computed.

Analysis

Larval sample data were subjected to Bartlett's Test of Homogeneity (Sokal and Rohlf 1969) and found to be nonhomogeneous. Therefore, raw data were transformed to $\text{Log}_{10}(x + 1)$ to stabilize variances, and were subjected to analysis of variance. Percent larval mortality data in postspray samples were also subjected to analyses of variance. Experimental power of the analyses of variance to detect statistically significant differences among treatments (Pearson and Hartley 1951) was computed for each sample day.

Spray deposit cards were viewed by a Quantimet Image Analyzer with a 44 mm lens which recorded spray drop stain sizes and stain size frequency and distribution. Mean spray deposit in gallons per acre and drops per cm^2 were computed using a modified U.S. Army computer program (ASCAS).

Plot mean defoliation indices were converted to numerical rank and treatment rank sums were analyzed nonparametrically to detect significant differences using the Kruskal-Wallis statistic (Sokal and Rohlf 1969).

We computed simple regressions of plot mean defoliation index over (a) mean number of cankerworm larvae in prespray samples, and (b) mean number of surviving cankerworm larvae at 9 days postspray, and computed a multiple regression of defoliation index over prespray larval numbers and spray deposit combined. In some cases, the data appear to fit curvilinear models more closely than linear models. However, because 3-dimensional curvilinear models are difficult to illustrate, the linear models are displayed to show that significant relationships exist.

RESULTS AND DISCUSSION

Application

Each treated shelterbelt plot was sprayed with a single 50-foot swath; therefore, treated area totaled 3 acres per ½-mile plot. The spray aircraft treatment time per ½-mile plot at 115 mph was 16 seconds, and 3 or 9 gallons of formulation were applied per ½-mile plot depending on assigned treatment. One and one-half pounds of Dipel were applied to each sprayed ½-mile belt.

A Cessna Ag Truck spraying 9 gallons of formulation per plot is capable of treating 15 half-mile belts per load, and 15 belts in the same or adjacent sections could easily be treated in ½ hour.

Spray Deposit

Spray deposited on sample Kromekote cards placed at the dripline of sample trees was quite variable and averaged less than 20 percent of the amount applied (table 1). However, each plot was sprayed with only a single swath, and light winds carried much of the spray downwind from some treated shelterbelts and deposited drops on drift sample Kromekote® cards. Best spray coverage occurred on plots treated at a rate of 3 gallons of spray per acre (table 1), and greatest percent control of larval populations occurred on those same plots (table 3a, figure 1). Higher percent population reduction in the 3-gallon per acre plots is attributed to better spray coverage on those plots because the amount of active ingredient (a.i.) measured in ounces of Bt deposited per acre was not significantly different among treatments (table 1).

Population Suppression

Larval population reduction at 9 days' postspray, the approximate life of most field-sampled Bt spores on foliage, was disappointingly low (tables 2a and 3a). Analysis of postspray larval numbers and percent larval mortalities, however, showed statistically significant differences between spray and check treatments on all postspray sample dates (tables 2b and 3b), but power of the experiment to detect truly significant differences was high only on the 5-day, 7-day, and 9-day postspray sample dates (tables 2c and 3c).

Although larval mortality appeared to level off at 7 days' postspray (figure 1), many surviving larvae appeared small and unhealthy in treated plots and feeding was substantially reduced. Larvae in untreated plots were large and healthy and continued feeding. Surviving larvae continued to feed after larval sampling was discontinued, and most defoliation occurred then.

Foliage Protection

Despite the unexpectedly low larval mortality at 9 days' postspray, defoliation was significantly lower in treated plots than in check plots at the end of larval feeding (table 4). This was not due entirely to spray treatment as the following discussion shows.

Defoliation index was low in plots where most Bt was deposited (figure 2), but also in plots where prespray larval numbers were low (figure 3). The independent variables, prespray larval numbers and spray deposit, both influenced postspray larval numbers (figure 4) which, in turn, influenced defoliation index (figure 5) the most of all 3 variables.

Treated foliage showed defoliation characteristic of feeding by young larvae on early leaves, but many late developing leaves were untouched. Untreated foliage was often completely consumed except for leaf midribs (figure 6). Ground and aerial views (figures 7 and 8) of treated and adjacent untreated belts show noticeable differences in defoliation intensity. Therefore, we believe that treatment in most cases provided adequate foliage protection, but that substantial larval mortality in treated plots was delayed until after the last postspray sample.

Night Spray Results

Analysis was unable to show significant mortality differences among spray treatments (table 3b). Lower mortality occurred in plots sprayed at a rate of 1 gallon per acre, but results in plots sprayed at night were no better than those sprayed during the day. The primary advantage of night spraying is reduced wind, but opportunities to spray successfully at night are limited because adequate moonlight, suitable spray weather, and cankerworm larval stage appropriate for treatment must coincide. In addition, night spraying is more dangerous because pilot vision is reduced, and the pilot requires substantially more time to find spray plots because of reduced visibility.

Economic Value of Shelterbelts

Bratkovich (1977) discusses two approaches to the economic valuation of shelterbelts, but disregards recreation, wildlife, and esthetic values.

The cost approach considers seedling, planting, past maintenance, tax, and interest. It values a 15-year-old, 2-acre shelterbelt at $2,770. The income approach considers cumulative crop protection value of a shelterbelt and discounts to the present at 6 percent the future protection value of a 40-year useful shelterbelt life. This approach values a ½-mile shelterbelt 26-35 feet high at $2,825. This valuation is modified by weather conditions because Van Deusen (1978) states that, generally, crop yields are increased significantly only when protection from wind is accompanied by adequate soil moisture.

Either valuation is appropriate for the size and age shelterbelts that we treated, but are not additive. Each indicates that cankerworm suppression to prolong shelterbelt life and to maintain crop protection efficiency is justified economically.

CONCLUSIONS

1. Aerially applied Bt at a rate of ½ lb. in 3 gallons of water per acre provided suitable and consistent protection of Siberian elm shelterbelts against defoliation by cankerworm larvae, but 1 gallon of formulation per acre provided less consistent results.

2. Night spraying is more hazardous and requires more time than day spraying, and spray opportunities are limited at night. Therefore, we conclude that night spraying offers few advantages over day spraying.

3. In order to better assess treatment effects on larval populations, postspray larval sampling should have been continued beyond 9 days' postspray until substantial numbers of larvae pupated.

4. The 1978 price of Dipel was about $7.80 per pound, and Shade cost $1.20 per pound. One and one-half pounds of Dipel and 1½ pounds of Shade per belt would cost $13.50. Therefore, the cost of treating a ½-mile shelterbelt with fixed-wing aircraft should cost approximately $20 to $30 depending on the number of belts sprayed per aircraft day.

5. The cost and income approaches to valuating shelterbelts each show that shelterbelts of the age, length, and height that we treated have an approximate present-day value of about $2,800 per belt. The landowner must decide whether shelterbelt foliage protection, and subsequent crop protection from the wind on adjacent acres justifies his expense for shelterbelt treatment.

Table 1.--Spray deposit summary.

Treatment (volume/acre and time of application)	Plot No.	vmd 1/	drops/cm^2	gal/acre	oz. Bt/acre 2/
		Spray deposit parameters			
3 gallon day	8	214.8	23.27	0.60	1.60
	9	240.6	7.26	0.33	0.88
	13	211.2	35.05	0.56	1.49
	19	202.5	29.38	0.50	1.33
	20	200.3	19.57	0.33	0.88
	29	221.0	11.15	0.35	0.93
	Mean ± S.E.	215.1 ± 6.0	20.95 ± 4.32	0.45 ± 0.05	1.19 ± 0.13
1 gallon day	7	216.6	0.09	0.00	0.00
	10	218.0	3.05	0.06	0.48
	14	208.9	9.96	0.28	2.24
	21	237.2	3.36	0.10	0.80
	24	207.1	15.75	0.32	2.56
	28	211.7	6.99	0.10	0.80
	Mean ± S.E.	216.6 ± 4.5	6.53 ± 2.31	0.14 ± 0.05	1.15 ± 0.42
1 gallon night	1	255.1	3.73	0.21	1.68
	3	241.4	5.42	0.29	2.32
	4	261.2	1.19	0.06	0.53
	15	208.2	12.83	0.23	1.84
	16	205.0	10.68	0.23	1.84
	27 3/	--	--	--	--
	Mean ± S.E.	234.2 ± 11.7	6.77 ± 2.17	0.20 ± 0.04	1.64 ± 0.30

1/ Spray drop volume medium diameter in microns.
2/ (Spray deposit in gal per acre/formulation applied in gal per acre) x 8 oz.
3/ Spray deposit cards were lost.

Table 2a--Pre- and postspray plot means and standard errors of cankerworm larval numbers per half meter branch sample.

Treatment (volume/acre and time of application)	Plot No.	Number of days postspray 0		2		5		7[1/]		9	
		$\overline{X}$	S.E.	$\overline{X}$	S.E.	$\overline{X}$	S.E.	$\overline{X}$	S.E	$\overline{X}$	S.E.
check	5	37.5	5.1	54.7	6.4	45.8	6.2	53.4	6.5	56.2	7.4
	6	30.3	5.1	42.5	5.0	34.2	3.9	59.9	8.2	43.8	6.0
	12	33.6	4.8	48.7	8.1	38.3	5.2	38.6	4.2	31.9	4.3
	17	57.8	5.4	60.6	6.1	65.5	6.3	35.4	3.1	45.9	5.0
	18	27.9	3.3	36.1	4.5	26.9	3.3	24.3	2.3	32.9	3.9
	26	18.2	2.0	29.3	4.1	26.4	3.0	21.2	1.9	21.3	2.5
	Mean	34.2		45.3		39.5		38.8		38.7	
3 gallon day	8	5.4	1.0	8.2	1.0	3.7	0.4	2.9	0.4	3.7	0.5
	9	7.9	1.4	9.6	1.6	5.5	0.7	3.1	0.7	4.3	1.0
	13	17.6	3.6	12.1	1.8	5.6	0.8	6.2	0.8	7.0	1.1
	19	16.8	1.9	8.4	1.1	4.0	0.6	6.8	0.8	3.3	0.6
	20	25.8	4.2	18.1	2.6	7.9	0.9	7.4	1.0	5.7	0.8
	29	31.3	3.9	17.0	1.6	13.3	1.9	10.5	1.5	13.2	2.1
	Mean	17.5		12.2		6.7		6.2		6.2	
1 gallon day	7	25.0	5.2	32.7	5.6	23.6	4.5	----	---	27.5	5.6
	10	35.3	6.6	41.9	6.9	33.6	4.1	----	---	28.0	4.9
	14	17.9	4.1	13.7	2.3	7.4	1.1	----	---	15.9	2.2
	21	13.6	1.7	14.0	1.5	6.9	1.1	----	---	6.0	0.8
	24	1.2	0.2	1.0	0.2	1.0	0.2	----	---	0.3	0.1
	28	7.8	1.2	5.7	0.9	2.5	0.4	----	---	2.5	0.5
	Mean	16.8		18.2		12.5				13.4	
1 gallon night	1	25.6	3.8	19.4	3.2	8.3	0.8	----	---	7.1	1.0
	3	16.5	2.5	23.4	3.5	28.0	3.9	----	---	15.2	1.8
	4	34.4	4.8	27.5	4.2	25.9	4.0	----	---	19.7	3.3
	15	1.5	0.3	1.2	0.3	0.3	0.1	----	---	0.5	0.1
	16	27.9	4.2	18.9	2.5	12.3	1.6	----	---	9.7	1.7
	27	14.2	1.8	19.7	2.4	15.7	1.7	----	---	14.3	1.7
	Mean	20.0		18.4		15.1				11.1	

1/ Only check plots and 3 gallon day plots were sampled at 7 days postspray.

Table 2b.--F-values among treatments of larval numbers data transformed to Log_{10} (x + 1) to stabilize variances.

Comparison	Number of days postspray 0	2	5	7	9
Spray tmts. and checks (degrees of freedom)	2.11 n.s. (3,20)	4.46* (3,20)	6.01** (3,20)	56.05** (1,10)	6.77** (3,20)
Spray tmts. only (degrees of freedom)	0.27 n.s. (2,15)	0.06 n.s. (2,15)	0.48 n.s. (2,15)	--- ---	0.33 n.s. (2,15)

n.s. = nonsignificantly different
* = significantly different at the 5 percent level.
** = significantly different at the 1 percent level.

Table 2c.--Percent chance of the experiment (experimental power) to detect a statistically significant difference (alpha =.05) between transformed spray treatment data and check data.

Number of days postspray 0	2	5	7	9
- - - -	- - -	Percent	- - -	- - -
42	65	84	99	88

Table 3a--Plot means of unadjusted percent[1/] larval mortality.

Treatment (volume/acre and time of application)	Plot No.	Number of days postspray 2	5	7	9
Check	5	-46	-22	-42	-50
	6	-40	-13	-98	-45
	12	-45	-14	-15	5
	17	- 5	-13	39	21
	18	-30	3	13	-18
	26	-61	-45	-16	-17
	Mean	-37.8	-17.3	-19.8	-17.3
3 gallon day	8	-51	32	47	31
	9	-22	30	61	46
	13	31	68	65	60
	19	50	76	59	80
	20	30	69	71	78
	29	46	57	66	58
	Mean	14.0	55.3	61.5	58.8
1 gallon day	7	-30	6	---	-10
	10	-19	5	---	21
	14	24	59	---	11
	21	- 3	49	---	56
	24	17	21	---	75
	28	27	68	---	68
	Mean	2.7	34.7	---	36.8
1 gallon night	1	24	68	---	72
	3	-42	-70	---	8
	4	20	25	---	43
	15	19	80	---	65
	16	32	56	---	65
	27	-39	-11	---	- 1
	Mean	2.3	24.7		42.0

1/ Percent mortality = $\left(1 - \frac{\text{postspray larval numbers}}{\text{prespray larval numbers}}\right)$ x 100; negative percent mortality results from an increase in larval numbers due to dispersal of young larvae from inner crown to crown periphery and dispersal by wind from adjacent belts.

Table 3b.--F-values among treatments of percent unadjusted mortalities.

Comparison	Number of days postspray 2	5	7	9
Spray tmts. and checks	3.33*	4.84*	17.23**	7.94*
(degrees of freedom)	(3,20)	(3,20_	(1,10)	(3,20)
Spray tmts. only	0.24 n.s.	1.00 n.s.	---	0.94 n.s.
(degrees of freedom)	(2,15)	(2,15)	---	(2,15)

n.s. = nonsignificantly different
 * = significantly different at the 5 percent level.
 ** = significantly different at the 1 percent level.

Table 3c.--Percent chance of the experiment (experimental power) to detect a statistically significant difference (alpha =.05) between unadjusted spray treatment and check mortalities.

Number of days postspray 2	5	7	9
- - - - - - - - - percent	- - - - - - - - -		
63	80	96	96

Table 4.--Plot mean defoliation indices converted to numerical rank and analyzed for significant differences nonparametrically[1/]

Treatment (volume per acre and time of application)	Plot number	Defoliation index	Rank(a)	Rank(b)
check	5	3.70	21	--
	6	4.60	24	--
	12	3.95	22	--
	17	4.25	23	--
	18	3.50	20	--
	26	2.22	17	--
			Sum = 127	
3 gallon day	8	1.05	4	4
	9	1.12	6	6
	13	1.42	11	11
	19	1.55	13	13
	20	1.28	9	9
	29	1.40	10	10
			Sum = 53	Sum = 53
1 gallon day	7	2.15	16	16
	10	2.50	19	18
	14	1.17	7	7
	21	1.25	8	8
	24	1.00	1	1
	28	1.02	2.5	2.5
			Sum = 53.5	Sum = 52.5
1 gallon night	1	1.10	5	5
	3	1.67	15	15
	4	2.45	18	17
	15	1.02	2.5	2.5
	16	1.62	14	14
	27	1.50	12	12
			Sum = 66.5	Sum = 65.5

1/ Rank Comparison	Kruskal-Wallis statistic
a) checks and spray treatments	12.414**
b) spray treatments only	0.65 n.s.

** = Significantly different at the 1 percent level.

FIG. I Postspray percent larval mortality was highest in the 3 gallon per acre treated plots and leveled off at 7 days postspray.

- negative percent mortalities represent increased larval numbers, plus/minus figures are standard errors of means

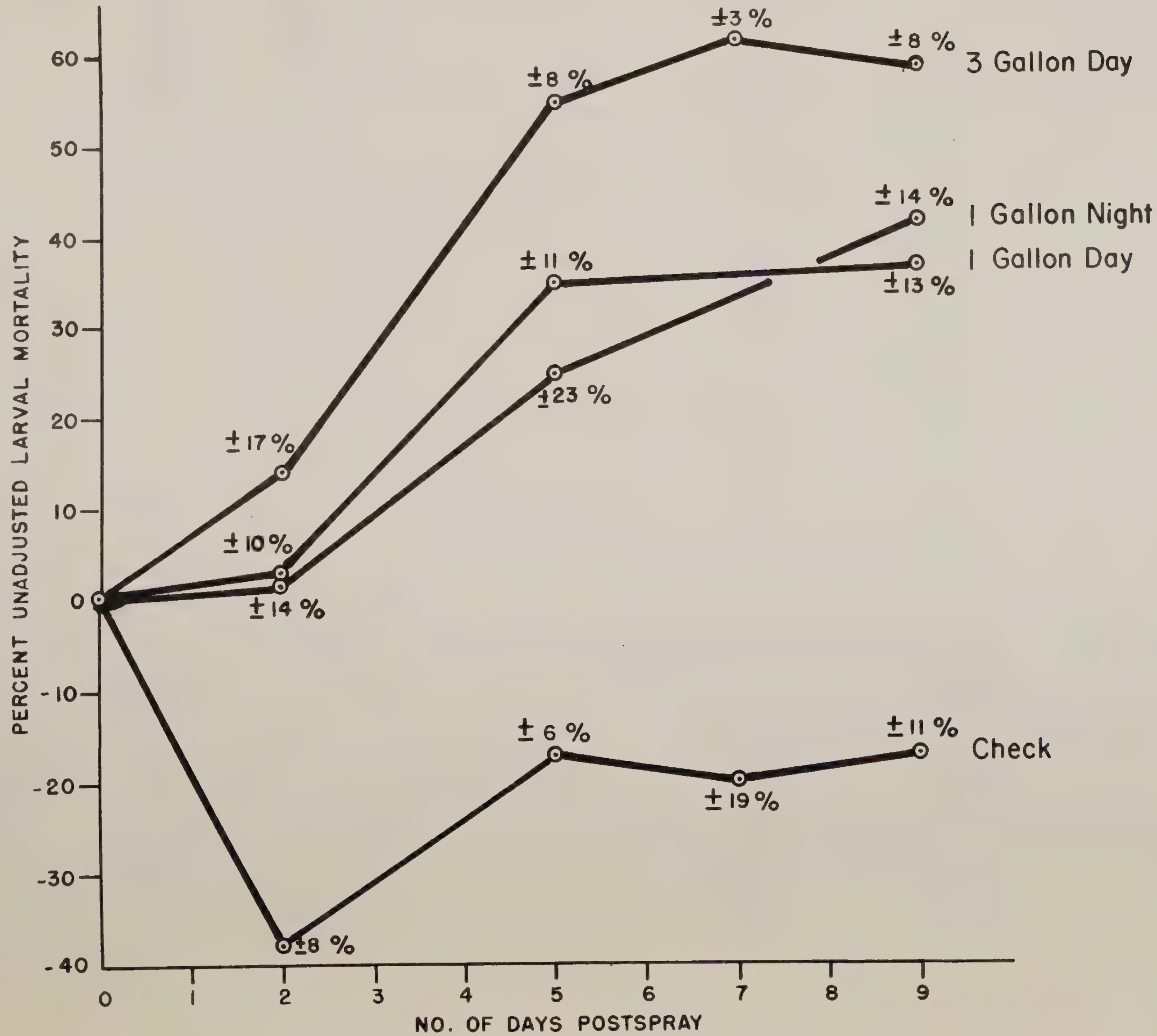

FIG. 2 Defoliation index decreased as amount of Bt deposited increased.

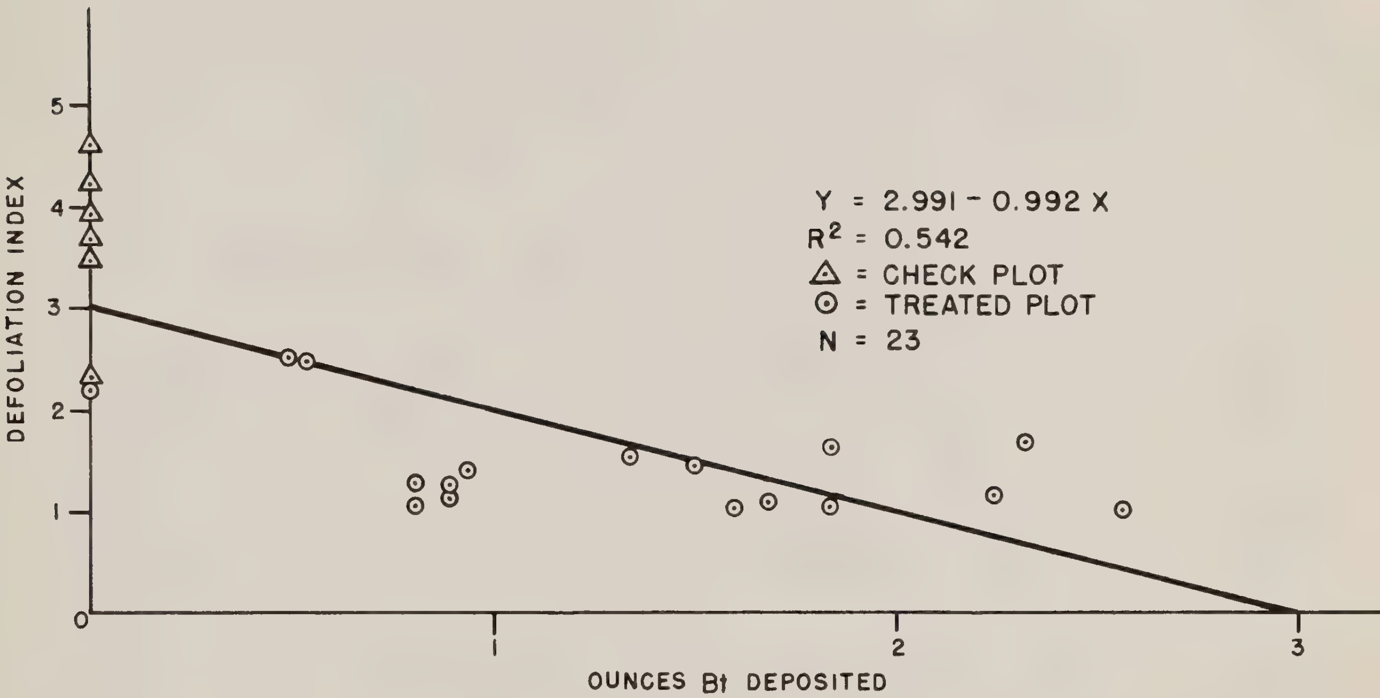

FIG. 3 Defoliation index increased with larger prespray larval numbers.

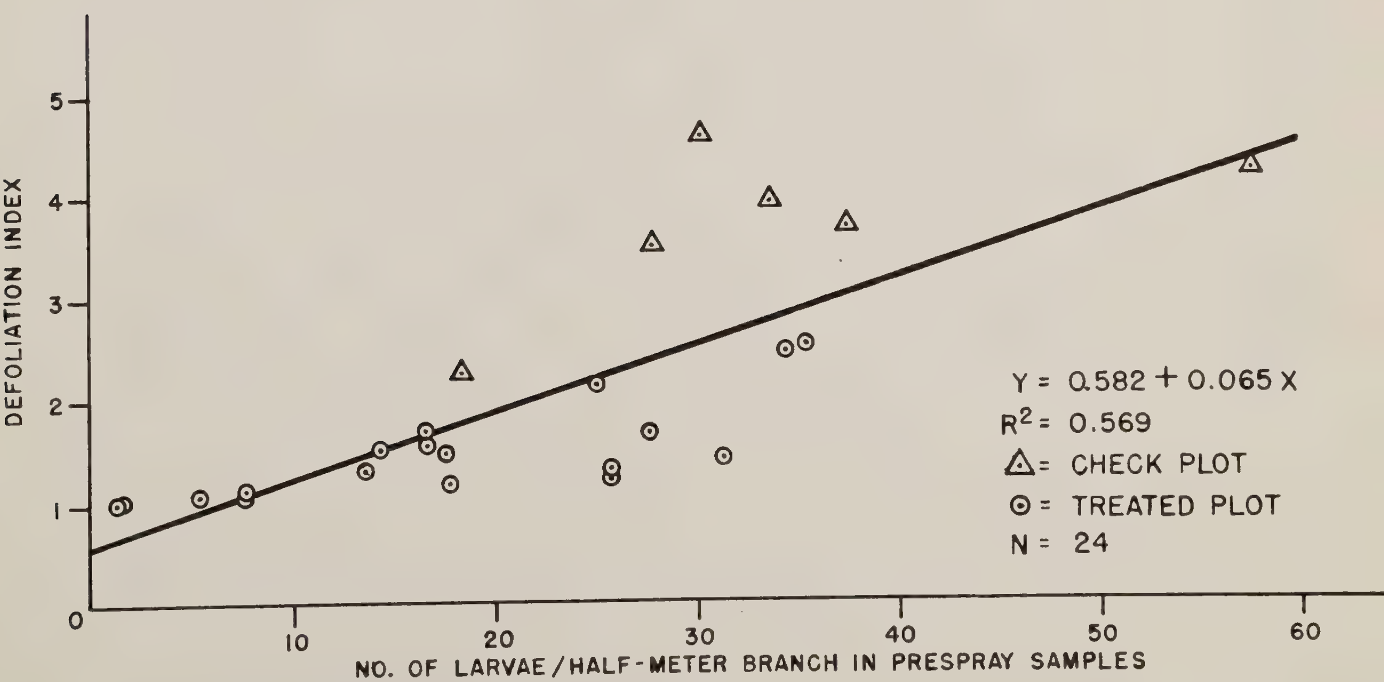

FIG. 4 Postspray larval numbers were low where prespray larval numbers were low and ounces of Bt deposited were high.

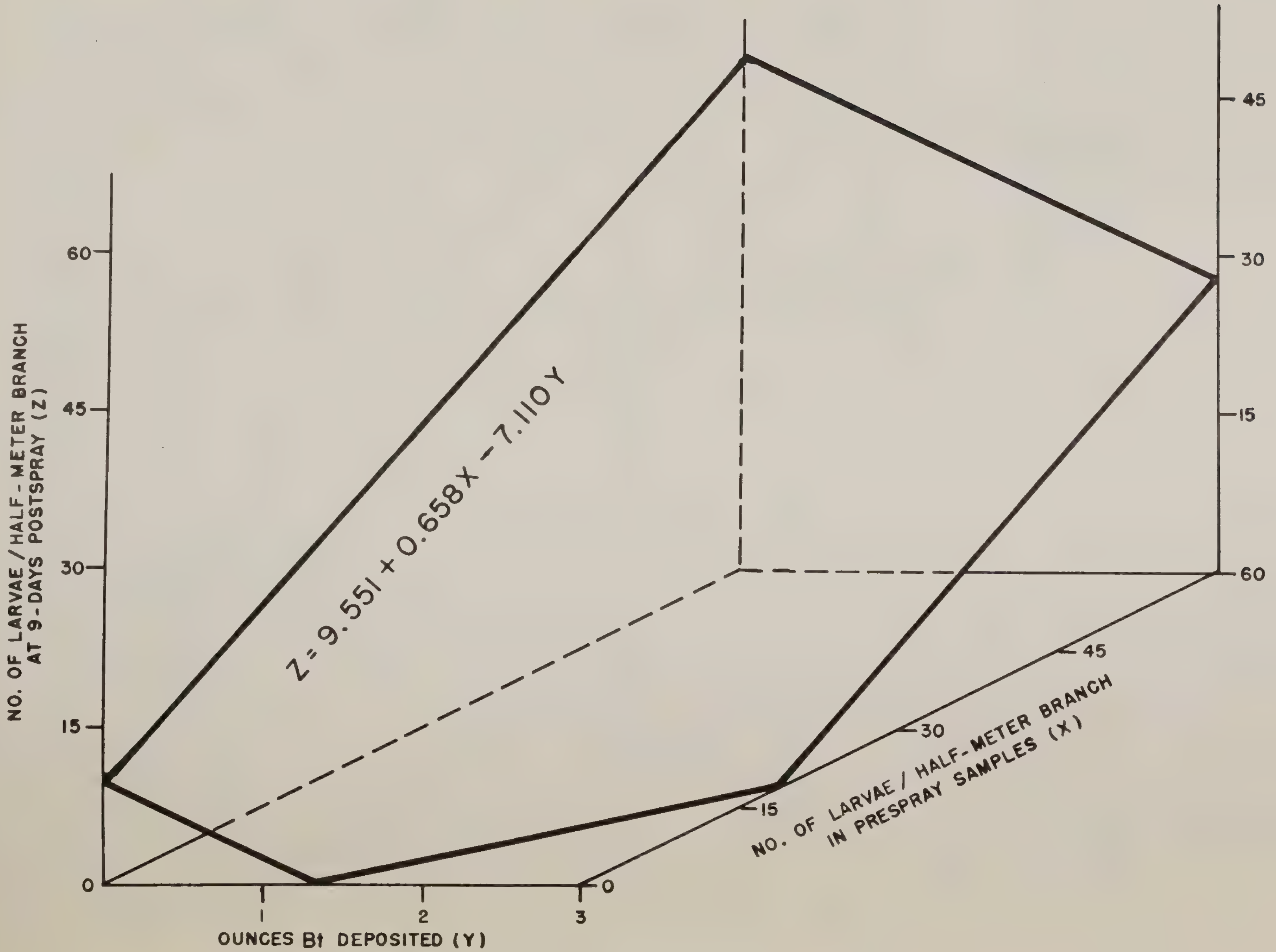

FIG. 5 Defoliation index is very closely related to postspray larval numbers

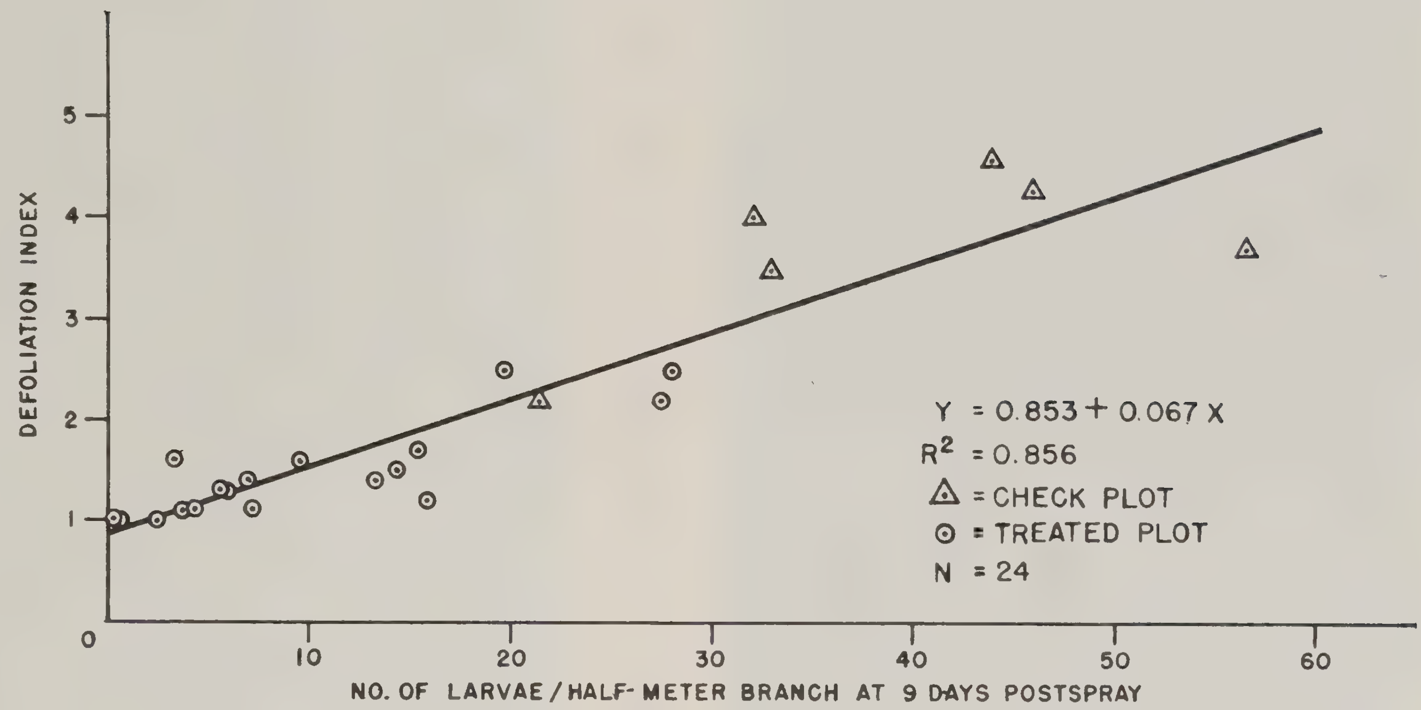

Figure 6 - Treated foliage is on left, untreated foliage from adjacent belt is on right.

Figure 7 - Treated belt is on near left, untreated belts are on far left and on right.

Figure 8 - Dark green belt at far end of section and dark green belt in middle were treated; remaining belts with much grey showing were untreated.

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